

Cave Volumetric Studies Based on Archive Maps of the Pál-völgy Cave (Hungary)

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Abstract. The Pál-völgy Cave under the hills of Budapest got into focus recently as in 2011 it became the largest cave system of Hungary with 28.6 km length. This study is about a pioneer modeling method which was able to predict the size of the cave system from archive cave maps. The modeling was primarily aimed to determine the volume of the cave in cubic meters and in percentage of the incorporating limestone and marl, but through this it revealed that approximately 2/3 of the cave is unexplored.

Keywords: volumetry, cave maps, 3D models, Pál-völgy Cave, cave size prediction

1. Introduction

The Pál-völgy Cave is part of the Buda Thermal Karst System which is a UNESCO World Heritage since 1993 (UNESCO 1993). Recent explorations revealed an extended cave-system (Pál-völgy Cave System) around the original cave (CaverInfo 2011), which is now the biggest in Hungary. Prior to this a volumetric model of the original Pál-völgy Cave was carried out.

Limestone cavity modeling was already present even before the digital era. Some cavers used their own survey data to create scaled plaster mock-ups (Jakucs 1948, Horváth 1965). The cavity volume ratio of the world's largest cave system, the Wind- and Jewel Cave in South Dakota was estimated by Conn (1966). He used a method, which is applicable only for caves with one entrance and produces volume calculation by measuring the air pressure inside and outside the cave and the air flow rate at the entrance. The Pál-völgy Cave has many connections with the surface, thus this method is not suitable in our case.

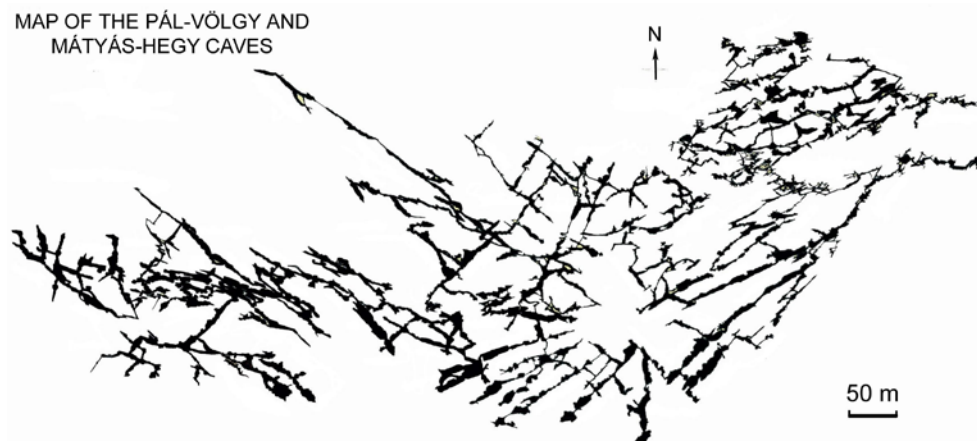


Figure 1. Directions of the corridors and passages of the cave are controlled by the NW-SE and NE-SW striking fault systems.

2. Volumetric cave model

The method for the volumetric model is based upon the segmentation of the cave passages, and on the method to produce volumes of each cave segment, using only the width (**w**) and height (**h**) of them. Numerical estimations for the punctuality of these models of the cave segments can be done at those places where the cave profiles were mapped (Kárpát 1983).

The explorers of the Pál-völgy Cave created reference points usually on every 5–10 m. These points are stored in pairs in the records. Each pair consists of a base point (*P*) and a measured point (*P_m*) and makes up a spatial vector (*Tab. 1*).

P (base)	P _m (measured)	Lenth [m]	Azimut [°]	Dip [°]	Notes
0	1	9,4	195,5	34,0	Main entrance
1	2	8,29	227,8	13,0	
2	3	3,66	195,0	-24,0	Lóczy-hall
3	4	5,90	195,0	-5,0	

Table 1. Interpretation of the original records of the cave-survey.

Coordinate geometrical functions and Visual Basic Scripts were used to convert the data of the original records into AutoCAD batch-orders, and finally into virtual 3D shapes (solids).

The reliability of the model was estimated with correlation of the mapped profiles of cave passages and the ones generated in the model for the same part of the cave. The correlation coefficient was 0.82–0.86. The difference

between the area of the generated and the mapped profile was also calculated at several points. The prospected value of the error was 13% relative to the mapped profile.

To estimate the rate of the cavities in relation with the incorporating rock body, statistical analysis was performed using small rock volumes. These small volumes were regular cubes in the model space with 50 m edge-length (Fig. 4), and they cut the cave model at random places covering both the high and low passage-density area.

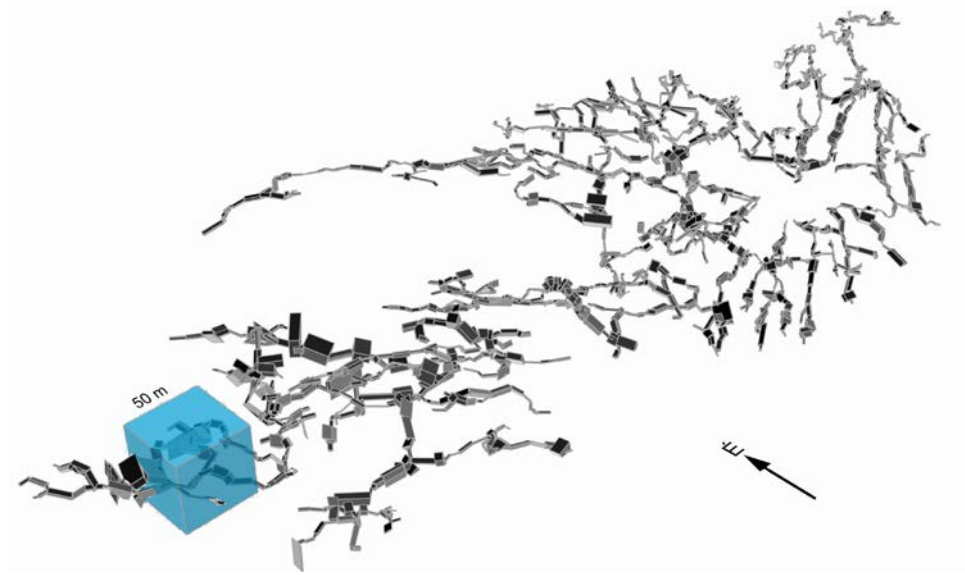


Figure 4. 3D model of the Pál-völgy Cave from SW with an 50 m edge-length cube model.

It was assumed that the resulting average ratio (1.46%) is valid for those passages which are not modeled, and not even mapped. In quantity and volume calculations this rate was considered as an "etalon" for the volumetric ratio ($\mathbf{a_e}$).

According to published data of caves with similar genetics (Weber and Bakker 1981, Palmer 1995, Heward et al. 2000), the rate of the cavity in the surrounding rock is 1-3%, which corresponds with the "etalon" volume ratio.

3. Results

In the *volumetric modelling* 2117 cave passages were processed. The total length is 12,177 m. Based on the model, the volume of cave passages was rounded to 72,700 m³.

It was also possible to deduce the volume of the unmapped passages (V_i) from the rate of the total enclosing rock mass (V_t), the percentage of the passage volume (a_t), and the known “etalon” percentage (a_e) (see equation 1).

$$(1) \quad V_i = \frac{(a_e - a_t) \cdot V_t}{100}$$

From these results, the total volume of the Pál-völgy Cave – without the Mátyás-hegy Cave – is close to 200,000 m³ and the length is around 33 km. Together with the connected Mátyás-hegy Cave and the known passages of the nearby caves of the Pál-völgy Cave System the estimated length of the passages is at least 44 km.

4. Conclusions

With the *volumetric model* of the Pál-völgy Cave, a first-time attempt have been made to exactly determine the volume of passages in a cave using maps, and to estimate the proportion of unexplored passages. These calculations suggested a significantly more extended cave system around the original Pál-völgy Cave prior to the explorations, which revealed so many new passages, that this cave system became the largest in the country.

References

- CaverInfo. 2011. Breakthrough Produces Hungary's Longest Cave System. In *CaverInfo*. <http://cavingnews.com/2011/216-breakthrough-produces-hungarys-longest-cave-system-szepvolgyi-harcsaszaju-hideglyuk-palvolgyi-matyashegyi>.
- Conn, H. W. (1966) Barometric Wind in Wind and Jewel Caves, South Dakota. *Bulletin of the National Speleological Society*, 28, 55–69.
- Heward, A. P., S. Chuenbunchom, G. Makel, D. Marsland & L. Spring (2000) Nang Nuan oil field, B6/27, Gulf of Thailand: karst reservoirs of meteoric or deep-burial origin? *Petroleum Geoscience*, 6, 15-27.

- Horváth, J. (1965) A Szemlőhegyi-barlang 1961-62. évi felmérése. *Karszt és Barlang*, 1965, 21–30.
- Jakucs, L. (1948) A hévforrásos barlangkeletkezés. *Hidrológiai Közlöny*, 28, 1–6.
- Kárpát, J. 1983. A Pál-völgyi-barlang. In *Magyarország Barlangtérképei*. Magyar Karszt és Barlangkutató Társulat.
- Palmer, A. N. 1995. *Wind Cave : an ancient world beneath the hills*. Hot Springs, S.D.: Black Hills Parks and Forests Association.
- UNESCO. 1993. Caves of the Buda Thermal Karst System. <http://whc.unesco.org/en/tentativelists/282/>; UNESCO.
- Weber, K. J. & M. Bakker. 1981. Fracture and vuggy porosity. In *Society of Petroleum Engineers Annual Technical Conference*. San Antonio, Texas.